

# 5



## ELASTICITY AND ITS APPLICATION

Imagine yourself as a Kansas wheat farmer. Because you earn all your income from selling wheat, you devote much effort to making your land as productive as it can be. You monitor weather and soil conditions, check your fields for pests and disease, and study the latest advances in farm technology. You know that the more wheat you grow, the more you will have to sell after the harvest, and the higher will be your income and your standard of living.

One day Kansas State University announces a major discovery. Researchers in its agronomy department have devised a new hybrid of wheat that raises the amount farmers can produce from each acre of land by 20 percent. How should you react to this news? Should you use the new hybrid? Does this discovery make you better off or worse off than you were before? In this chapter we will see that these questions can have surprising answers. The surprise will come from

IN THIS CHAPTER  
YOU WILL . . .

*Learn the meaning  
of the elasticity of  
demand*

*Examine what  
determines the  
elasticity of demand*

*Learn the meaning  
of the elasticity of  
supply*

*Examine what  
determines the  
elasticity of supply*

*Apply the concept of  
elasticity in three  
very different  
markets*

applying the most basic tools of economics—supply and demand—to the market for wheat.

The previous chapter introduced supply and demand. In any competitive market, such as the market for wheat, the upward-sloping supply curve represents the behavior of sellers, and the downward-sloping demand curve represents the behavior of buyers. The price of the good adjusts to bring the quantity supplied and quantity demanded of the good into balance. To apply this basic analysis to understand the impact of the agronomists' discovery, we must first develop one more tool: the concept of *elasticity*. Elasticity, a measure of how much buyers and sellers respond to changes in market conditions, allows us to analyze supply and demand with greater precision.

## THE ELASTICITY OF DEMAND

When we discussed the determinants of demand in Chapter 4, we noted that buyers usually demand more of a good when its price is lower, when their incomes are higher, when the prices of substitutes for the good are higher, or when the prices of complements of the good are lower. Our discussion of demand was qualitative, not quantitative. That is, we discussed the direction in which the quantity demanded moves, but not the size of the change. To measure how much demand responds to changes in its determinants, economists use the concept of **elasticity**.

### **elasticity**

*a measure of the responsiveness of quantity demanded or quantity supplied to one of its determinants*

## THE PRICE ELASTICITY OF DEMAND AND ITS DETERMINANTS

The law of demand states that a fall in the price of a good raises the quantity demanded. The **price elasticity of demand** measures how much the quantity demanded responds to a change in price. Demand for a good is said to be *elastic* if the quantity demanded responds substantially to changes in the price. Demand is said to be *inelastic* if the quantity demanded responds only slightly to changes in the price.

What determines whether the demand for a good is elastic or inelastic? Because the demand for any good depends on consumer preferences, the price elasticity of demand depends on the many economic, social, and psychological forces that shape individual desires. Based on experience, however, we can state some general rules about what determines the price elasticity of demand.

**Necessities versus Luxuries** Necessities tend to have inelastic demands, whereas luxuries have elastic demands. When the price of a visit to the doctor rises, people will not dramatically alter the number of times they go to the doctor, although they might go somewhat less often. By contrast, when the price of sailboats rises, the quantity of sailboats demanded falls substantially. The reason is that most people view doctor visits as a necessity and sailboats as a luxury. Of course, whether a good is a necessity or a luxury depends not on the intrinsic properties of the good but on the preferences of the buyer. For an avid sailor with

### **price elasticity of demand**

*a measure of how much the quantity demanded of a good responds to a change in the price of that good, computed as the percentage change in quantity demanded divided by the percentage change in price*

little concern over his health, sailboats might be a necessity with inelastic demand and doctor visits a luxury with elastic demand.

**Availability of Close Substitutes** Goods with close substitutes tend to have more elastic demand because it is easier for consumers to switch from that good to others. For example, butter and margarine are easily substitutable. A small increase in the price of butter, assuming the price of margarine is held fixed, causes the quantity of butter sold to fall by a large amount. By contrast, because eggs are a food without a close substitute, the demand for eggs is probably less elastic than the demand for butter.

**Definition of the Market** The elasticity of demand in any market depends on how we draw the boundaries of the market. Narrowly defined markets tend to have more elastic demand than broadly defined markets, because it is easier to find close substitutes for narrowly defined goods. For example, food, a broad category, has a fairly inelastic demand because there are no good substitutes for food. Ice cream, a more narrow category, has a more elastic demand because it is easy to substitute other desserts for ice cream. Vanilla ice cream, a very narrow category, has a very elastic demand because other flavors of ice cream are almost perfect substitutes for vanilla.

**Time Horizon** Goods tend to have more elastic demand over longer time horizons. When the price of gasoline rises, the quantity of gasoline demanded falls only slightly in the first few months. Over time, however, people buy more fuel-efficient cars, switch to public transportation, and move closer to where they work. Within several years, the quantity of gasoline demanded falls substantially.

## COMPUTING THE PRICE ELASTICITY OF DEMAND

Now that we have discussed the price elasticity of demand in general terms, let's be more precise about how it is measured. Economists compute the price elasticity of demand as the percentage change in the quantity demanded divided by the percentage change in the price. That is,

$$\text{Price elasticity of demand} = \frac{\text{Percentage change in quantity demanded}}{\text{Percentage change in price}}.$$

For example, suppose that a 10-percent increase in the price of an ice-cream cone causes the amount of ice cream you buy to fall by 20 percent. We calculate your elasticity of demand as

$$\text{Price elasticity of demand} = \frac{20 \text{ percent}}{10 \text{ percent}} = 2.$$

In this example, the elasticity is 2, reflecting that the change in the quantity demanded is proportionately twice as large as the change in the price.

Because the quantity demanded of a good is negatively related to its price, the percentage change in quantity will always have the opposite sign as the

percentage change in price. In this example, the percentage change in price is a *positive* 10 percent (reflecting an increase), and the percentage change in quantity demanded is a *negative* 20 percent (reflecting a decrease). For this reason, price elasticities of demand are sometimes reported as negative numbers. In this book we follow the common practice of dropping the minus sign and reporting all price elasticities as positive numbers. (Mathematicians call this the *absolute value*.) With this convention, a larger price elasticity implies a greater responsiveness of quantity demanded to price.

### THE MIDPOINT METHOD: A BETTER WAY TO CALCULATE PERCENTAGE CHANGES AND ELASTICITIES

If you try calculating the price elasticity of demand between two points on a demand curve, you will quickly notice an annoying problem: The elasticity from point A to point B seems different from the elasticity from point B to point A. For example, consider these numbers:

Point A: Price = \$4    Quantity = 120  
 Point B: Price = \$6    Quantity = 80

Going from point A to point B, the price rises by 50 percent, and the quantity falls by 33 percent, indicating that the price elasticity of demand is  $33/50$ , or 0.66. By contrast, going from point B to point A, the price falls by 33 percent, and the quantity rises by 50 percent, indicating that the price elasticity of demand is  $50/33$ , or 1.5.

One way to avoid this problem is to use the *midpoint method* for calculating elasticities. Rather than computing a percentage change using the standard way (by dividing the change by the initial level), the midpoint method computes a percentage change by dividing the change by the midpoint of the initial and final levels. For instance, \$5 is the midpoint of \$4 and \$6. Therefore, according to the midpoint method, a change from \$4 to \$6 is considered a 40 percent rise, because  $(6 - 4)/5 \times 100 = 40$ . Similarly, a change from \$6 to \$4 is considered a 40 percent fall.

Because the midpoint method gives the same answer regardless of the direction of change, it is often used when calculating the price elasticity of demand between two points. In our example, the midpoint between point A and point B is:

Midpoint:    Price = \$5    Quantity = 100

According to the midpoint method, when going from point A to point B, the price rises by 40 percent, and the quantity falls by 40 percent. Similarly, when going from point B to point A, the price falls by 40 percent, and the quantity rises by 40 percent. In both directions, the price elasticity of demand equals 1.

We can express the midpoint method with the following formula for the price elasticity of demand between two points, denoted  $(Q_1, P_1)$  and  $(Q_2, P_2)$ :

$$\text{Price elasticity of demand} = \frac{(Q_2 - Q_1)/[(Q_2 + Q_1)/2]}{(P_2 - P_1)/[(P_2 + P_1)/2]}$$

The numerator is the percentage change in quantity computed using the midpoint method, and the denominator is the percentage change in price computed using the midpoint method. If you ever need to calculate elasticities, you should use this formula.

Throughout this book, however, we only rarely need to perform such calculations. For our purposes, what elasticity represents—the responsiveness of quantity demanded to price—is more important than how it is calculated.

## THE VARIETY OF DEMAND CURVES

Economists classify demand curves according to their elasticity. Demand is *elastic* when the elasticity is greater than 1, so that quantity moves proportionately more than the price. Demand is *inelastic* when the elasticity is less than 1, so that quantity moves proportionately less than the price. If the elasticity is exactly 1, so that quantity moves the same amount proportionately as price, demand is said to have *unit elasticity*.

Because the price elasticity of demand measures how much quantity demanded responds to changes in the price, it is closely related to the slope of the demand curve. The following rule of thumb is a useful guide: The flatter is the demand curve that passes through a given point, the greater is the price elasticity of demand. The steeper is the demand curve that passes through a given point, the smaller is the price elasticity of demand.

Figure 5-1 shows five cases. In the extreme case of a zero elasticity, demand is *perfectly inelastic*, and the demand curve is vertical. In this case, regardless of the price, the quantity demanded stays the same. As the elasticity rises, the demand curve gets flatter and flatter. At the opposite extreme, demand is *perfectly elastic*. This occurs as the price elasticity of demand approaches infinity and the demand curve becomes horizontal, reflecting the fact that very small changes in the price lead to huge changes in the quantity demanded.

Finally, if you have trouble keeping straight the terms *elastic* and *inelastic*, here's a memory trick for you: Inelastic curves, such as in panel (a) of Figure 5-1, look like the letter *I*. Elastic curves, as in panel (e), look like the letter *E*. This is not a deep insight, but it might help on your next exam.

## TOTAL REVENUE AND THE PRICE ELASTICITY OF DEMAND

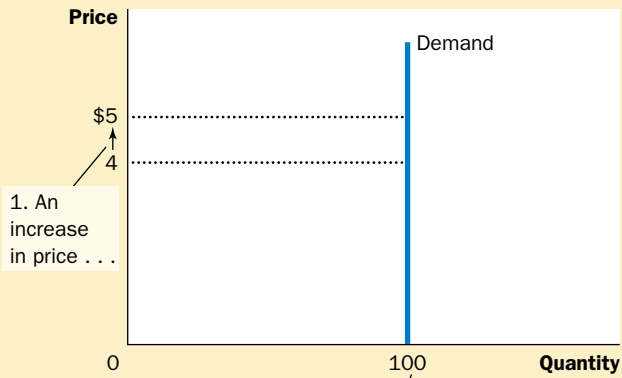
When studying changes in supply or demand in a market, one variable we often want to study is **total revenue**, the amount paid by buyers and received by sellers of the good. In any market, total revenue is  $P \times Q$ , the price of the good times the quantity of the good sold. We can show total revenue graphically, as in Figure 5-2. The height of the box under the demand curve is  $P$ , and the width is  $Q$ . The area of this box,  $P \times Q$ , equals the total revenue in this market. In Figure 5-2, where  $P = \$4$  and  $Q = 100$ , total revenue is  $\$4 \times 100$ , or \$400.

How does total revenue change as one moves along the demand curve? The answer depends on the price elasticity of demand. If demand is inelastic, as in Figure 5-3, then an increase in the price causes an increase in total revenue. Here an increase in price from \$1 to \$3 causes the quantity demanded to fall only from 100

### **total revenue**

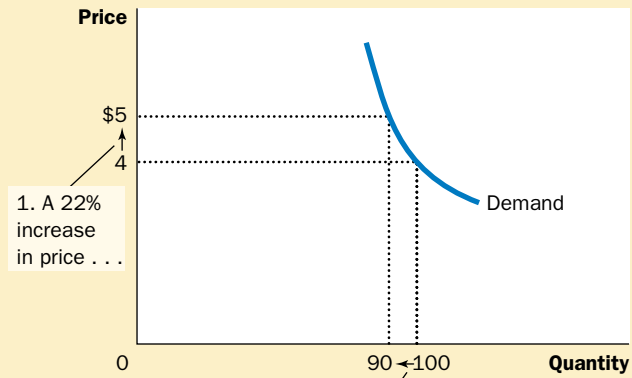
*the amount paid by buyers and received by sellers of a good, computed as the price of the good times the quantity sold*

(a) Perfectly Inelastic Demand: Elasticity Equals 0



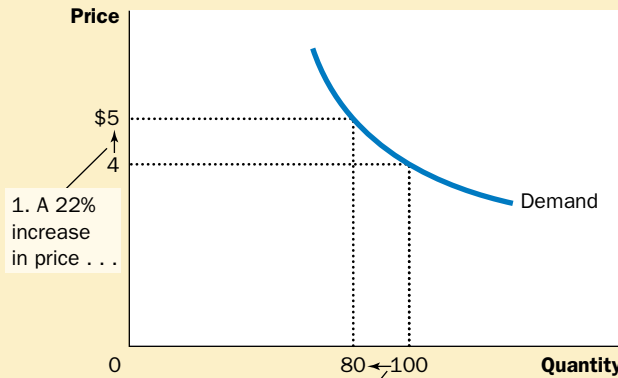
2. . . . leaves the quantity demanded unchanged.

(b) Inelastic Demand: Elasticity Is Less Than 1



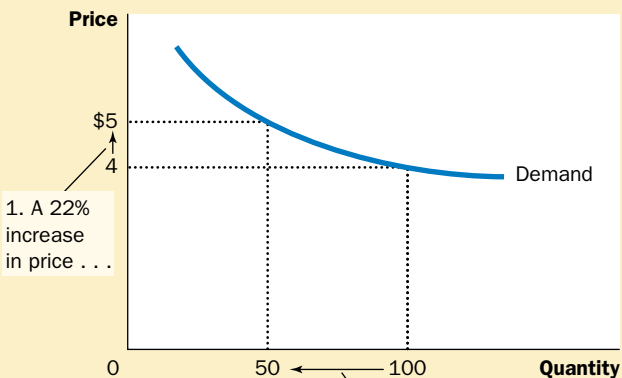
2. . . . leads to an 11% decrease in quantity demanded.

(c) Unit Elastic Demand: Elasticity Equals 1



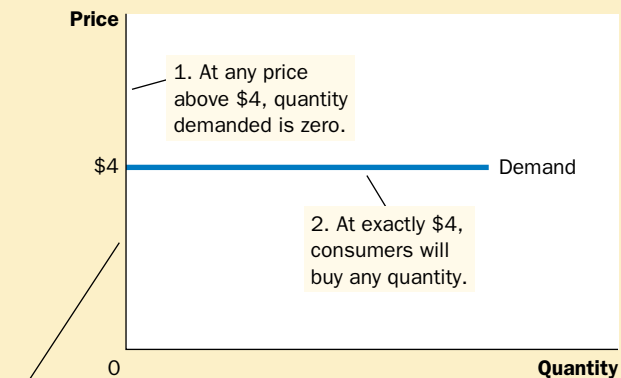
2. . . . leads to a 22% decrease in quantity demanded.

(d) Elastic Demand: Elasticity Is Greater Than 1



2. . . . leads to a 67% decrease in quantity demanded.

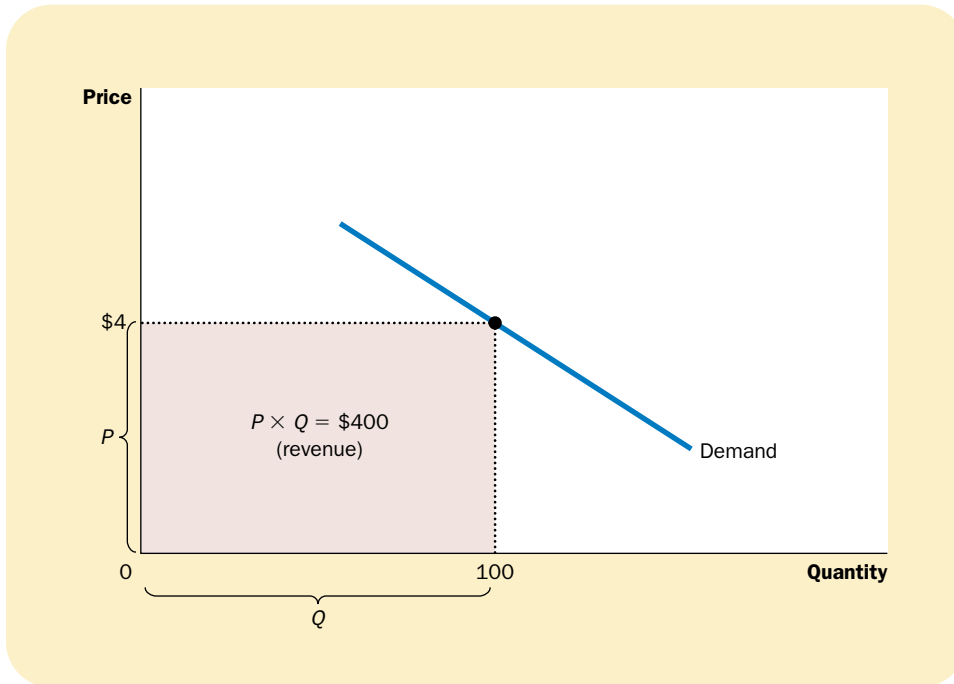
(e) Perfectly Elastic Demand: Elasticity Equals Infinity



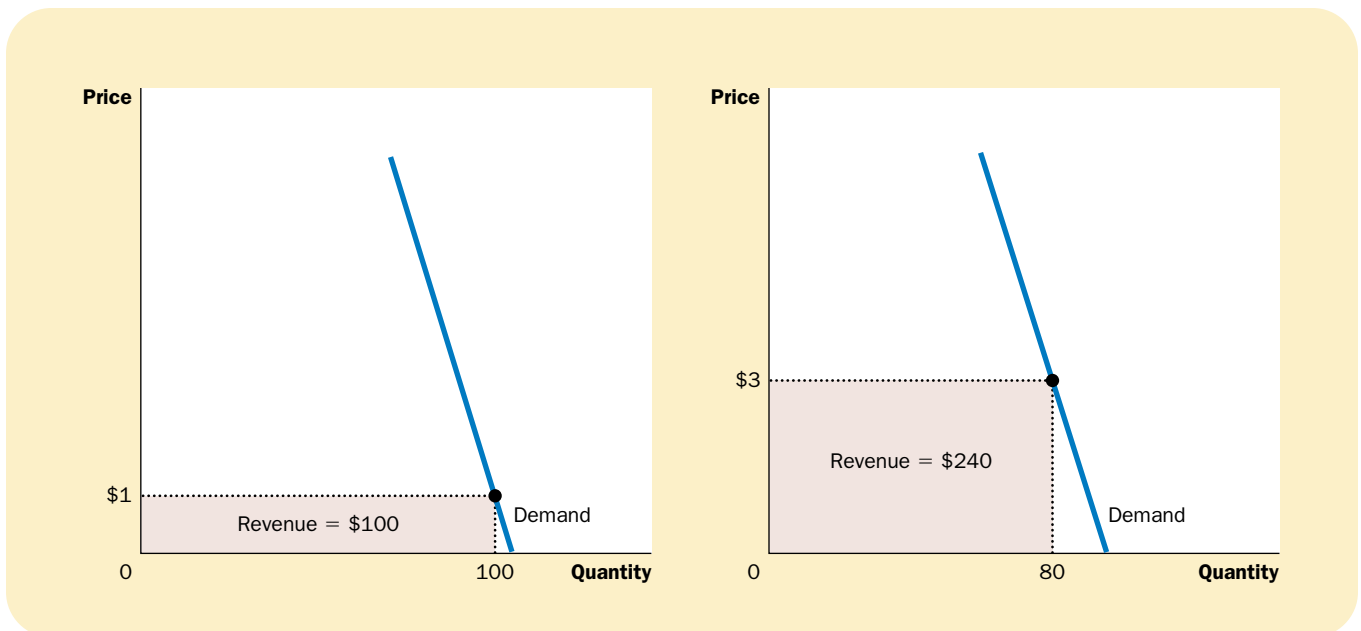
3. At a price below \$4, quantity demanded is infinite.

Figure 5-1

THE PRICE ELASTICITY OF DEMAND. The price elasticity of demand determines whether the demand curve is steep or flat. Note that all percentage changes are calculated using the midpoint method.

**Figure 5-2**

**TOTAL REVENUE.** The total amount paid by buyers, and received as revenue by sellers, equals the area of the box under the demand curve,  $P \times Q$ . Here, at a price of \$4, the quantity demanded is 100, and total revenue is \$400.



**HOW TOTAL REVENUE CHANGES WHEN PRICE CHANGES: INELASTIC DEMAND.** With an inelastic demand curve, an increase in the price leads to a decrease in quantity demanded that is proportionately smaller. Therefore, total revenue (the product of price and quantity) increases. Here, an increase in the price from \$1 to \$3 causes the quantity demanded to fall from 100 to 80, and total revenue rises from \$100 to \$240.

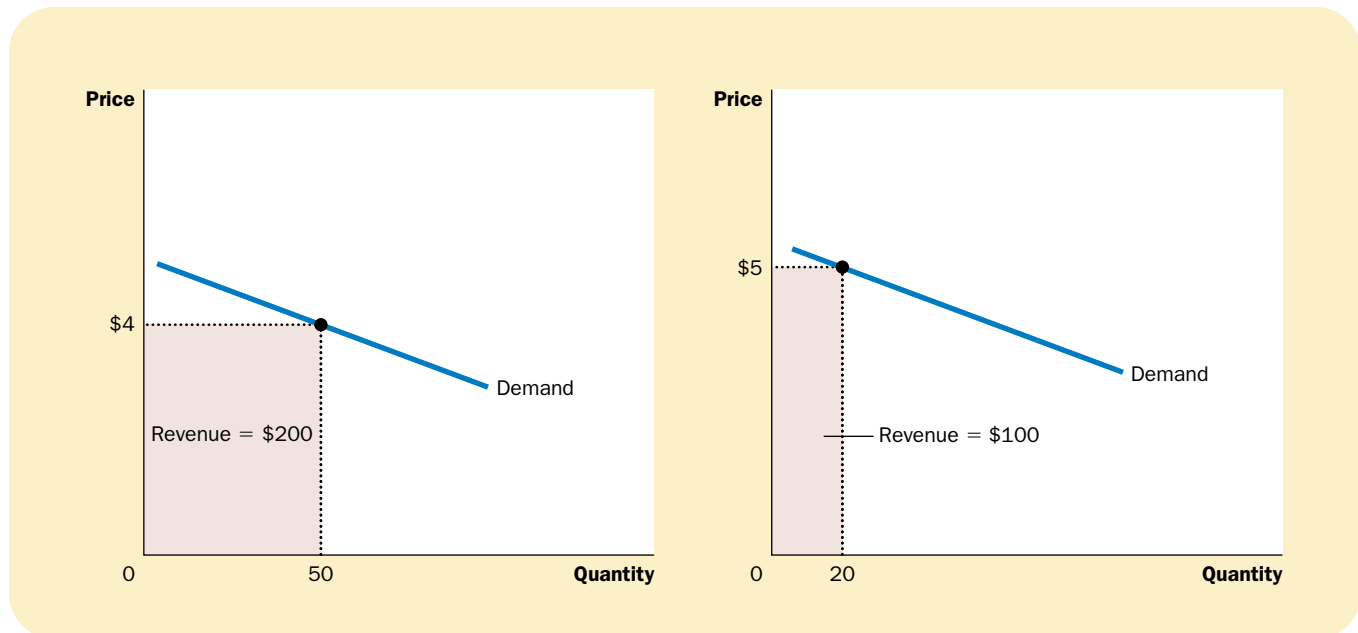
**Figure 5-3**

to 80, and so total revenue rises from \$100 to \$240. An increase in price raises  $P \times Q$  because the fall in  $Q$  is proportionately smaller than the rise in  $P$ .

We obtain the opposite result if demand is elastic: An increase in the price causes a decrease in total revenue. In Figure 5-4, for instance, when the price rises from \$4 to \$5, the quantity demanded falls from 50 to 20, and so total revenue falls from \$200 to \$100. Because demand is elastic, the reduction in the quantity demanded is so great that it more than offsets the increase in the price. That is, an increase in price reduces  $P \times Q$  because the fall in  $Q$  is proportionately greater than the rise in  $P$ .

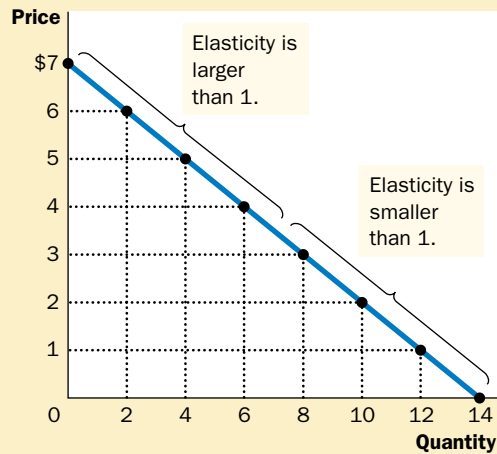
Although the examples in these two figures are extreme, they illustrate a general rule:

- ◆ When a demand curve is inelastic (a price elasticity less than 1), a price increase raises total revenue, and a price decrease reduces total revenue.
- ◆ When a demand curve is elastic (a price elasticity greater than 1), a price increase reduces total revenue, and a price decrease raises total revenue.
- ◆ In the special case of unit elastic demand (a price elasticity exactly equal to 1), a change in the price does not affect total revenue.



**Figure 5-4**

HOW TOTAL REVENUE CHANGES WHEN PRICE CHANGES: ELASTIC DEMAND. With an elastic demand curve, an increase in the price leads to a decrease in quantity demanded that is proportionately larger. Therefore, total revenue (the product of price and quantity) decreases. Here, an increase in the price from \$4 to \$5 causes the quantity demanded to fall from 50 to 20, so total revenue falls from \$200 to \$100.

**Figure 5-5**

A LINEAR DEMAND CURVE. The slope of a linear demand curve is constant, but its elasticity is not.

## ELASTICITY AND TOTAL REVENUE ALONG A LINEAR DEMAND CURVE

Although some demand curves have an elasticity that is the same along the entire curve, that is not always the case. An example of a demand curve along which elasticity changes is a straight line, as shown in Figure 5-5. A linear demand curve has a constant slope. Recall that slope is defined as “rise over run,” which here is the ratio of the change in price (“rise”) to the change in quantity (“run”). This particular demand curve’s slope is constant because each \$1 increase in price causes the same 2-unit decrease in the quantity demanded.

Even though the slope of a linear demand curve is constant, the elasticity is not. The reason is that the slope is the ratio of *changes* in the two variables, whereas the elasticity is the ratio of *percentage changes* in the two variables. You can see this most easily by looking at Table 5-1. This table shows the demand schedule for the linear demand curve in Figure 5-5 and calculates the price elasticity of demand using the midpoint method discussed earlier. At points with low price and high quantity, the demand curve is inelastic. At points with a high price and low quantity, the demand curve is elastic.

Table 5-1 also presents total revenue at each point on the demand curve. These numbers illustrate the relationship between total revenue and elasticity. When the price is \$1, for instance, demand is inelastic, and a price increase to \$2 raises total revenue. When the price is \$5, demand is elastic, and a price increase to \$6 reduces total revenue. Between \$3 and \$4, demand is exactly unit elastic, and total revenue is the same at these two prices.

### CASE STUDY PRICING ADMISSION TO A MUSEUM

You are curator of a major art museum. Your director of finance tells you that the museum is running short of funds and suggests that you consider changing



IF THE PRICE OF ADMISSION WERE HIGHER, HOW MUCH SHORTER WOULD THIS LINE BECOME?

the price of admission to increase total revenue. What do you do? Do you raise the price of admission, or do you lower it?

The answer depends on the elasticity of demand. If the demand for visits to the museum is inelastic, then an increase in the price of admission would increase total revenue. But if the demand is elastic, then an increase in price would cause the number of visitors to fall by so much that total revenue would decrease. In this case, you should cut the price. The number of visitors would rise by so much that total revenue would increase.

To estimate the price elasticity of demand, you would need to turn to your statisticians. They might use historical data to study how museum attendance varied from year to year as the admission price changed. Or they might use data on attendance at the various museums around the country to see how the admission price affects attendance. In studying either of these sets of data, the statisticians would need to take account of other factors that affect attendance—weather, population, size of collection, and so forth—in order to isolate the effect of price. In the end, such data analysis would provide an estimate of the price elasticity of demand, which you could use in deciding how to respond to your financial problem.

**income elasticity of demand**

*a measure of how much the quantity demanded of a good responds to a change in consumers' income, computed as the percentage change in quantity demanded divided by the percentage change in income*

**OTHER DEMAND ELASTICITIES**

In addition to the price elasticity of demand, economists also use other elasticities to describe the behavior of buyers in a market.

**The Income Elasticity of Demand** Economists use the **income elasticity of demand** to measure how the quantity demanded changes as consumer income changes. The income elasticity is the percentage change in quantity demanded divided by the percentage change in income. That is,

PRICE	QUANTITY	TOTAL REVENUE (PRICE × QUANTITY)	PERCENT CHANGE IN PRICE	PERCENT CHANGE IN QUANTITY	ELASTICITY	DESCRIPTION
\$7	0	\$ 0				
6	2	12	15	200	13.0	Elastic
5	4	20	18	67	3.7	Elastic
4	6	24	22	40	1.8	Elastic
3	8	24	29	29	1.0	Unit elastic
2	10	20	40	22	0.6	Inelastic
1	12	12	67	18	0.3	Inelastic
0	14	0	200	15	0.1	Inelastic

**Table 5-1**

COMPUTING THE ELASTICITY OF A LINEAR DEMAND CURVE

NOTE: Elasticity is calculated here using the midpoint method.

**IN THE NEWS***On the Road  
with Elasticity*

HOW SHOULD A FIRM THAT OPERATES A private toll road set a price for its service? As the following article makes clear, answering this question requires an understanding of the demand curve and its elasticity.

**For Whom the Booth Tolls,  
Price Really Does Matter**

BY STEVEN PEARLSTEIN

All businesses face a similar question: What price for their product will generate the maximum profit?

The answer is not always obvious: Raising the price of something often has the effect of reducing sales as price-sensitive consumers seek alternatives or simply do without. For every product, the extent of that sensitivity is different. The trick is to find the point for each where the ideal tradeoff between profit margin and sales volume is achieved.

Right now, the developers of a new private toll road between Leesburg and

Washington-Dulles International Airport are trying to discern the magic point. The group originally projected that it could charge nearly \$2 for the 14-mile one-way trip, while attracting 34,000 trips on an average day from overcrowded public roads such as nearby Route 7. But after spending \$350 million to build their much heralded "Greenway," they discovered to their dismay that only about a third that number of commuters were willing to pay that much to shave 20 minutes off their daily commute. . . .

It was only when the company, in desperation, lowered the toll to \$1 that it came even close to attracting the expected traffic flows.

Although the Greenway still is losing money, it is clearly better off at this new point on the demand curve than it was when it first opened. Average daily revenue today is \$22,000, compared with \$14,875 when the "special introductory" price was \$1.75. And with traffic still light even at rush hour, it is possible that the owners may lower tolls even further in search of higher revenue.

After all, when the price was lowered by 45 percent last spring, it generated a 200 percent increase in volume three months later. If the same ratio applies again, lowering the toll another 25 percent would drive the daily volume up to 38,000 trips, and daily revenue up to nearly \$29,000.

The problem, of course, is that the same ratio usually does not apply at

every price point, which is why this pricing business is so tricky. . . .

Clifford Winston of the Brookings Institution and John Calfee of the American Enterprise Institute have considered the toll road's dilemma. . . .

Last year, the economists conducted an elaborate market test with 1,170 people across the country who were each presented with a series of options in which they were, in effect, asked to make a personal tradeoff between less commuting time and higher tolls.

In the end, they concluded that the people who placed the highest value on reducing their commuting time already had done so by finding public transportation, living closer to their work, or selecting jobs that allowed them to commute at off-peak hours.

Conversely, those who commuted significant distances had a higher tolerance for traffic congestion and were willing to pay only 20 percent of their hourly pay to save an hour of their time.

Overall, the Winston/Calfee findings help explain why the Greenway's original toll and volume projections were too high: By their reckoning, only commuters who earned at least \$30 an hour (about \$60,000 a year) would be willing to pay \$2 to save 20 minutes.

SOURCE: *The Washington Post*, October 24, 1996, p. E1.

$$\text{Income elasticity of demand} = \frac{\text{Percentage change in quantity demanded}}{\text{Percentage change in income}}$$

As we discussed in Chapter 4, most goods are *normal goods*: Higher income raises quantity demanded. Because quantity demanded and income move in the same direction, normal goods have positive income elasticities. A few goods, such as bus

rides, are *inferior goods*: Higher income lowers the quantity demanded. Because quantity demanded and income move in opposite directions, inferior goods have negative income elasticities.

Even among normal goods, income elasticities vary substantially in size. Necessities, such as food and clothing, tend to have small income elasticities because consumers, regardless of how low their incomes, choose to buy some of these goods. Luxuries, such as caviar and furs, tend to have large income elasticities because consumers feel that they can do without these goods altogether if their income is too low.

### cross-price elasticity of demand

*a measure of how much the quantity demanded of one good responds to a change in the price of another good, computed as the percentage change in quantity demanded of the first good divided by the percentage change in the price of the second good*

**The Cross-Price Elasticity of Demand** Economists use the **cross-price elasticity of demand** to measure how the quantity demanded of one good changes as the price of another good changes. It is calculated as the percentage change in quantity demanded of good 1 divided by the percentage change in the price of good 2. That is,

$$\text{Cross-price elasticity of demand} = \frac{\text{Percentage change in quantity demanded of good 1}}{\text{Percentage change in the price of good 2}}$$

Whether the cross-price elasticity is a positive or negative number depends on whether the two goods are substitutes or complements. As we discussed in Chapter 4, substitutes are goods that are typically used in place of one another, such as hamburgers and hot dogs. An increase in hot dog prices induces people to grill hamburgers instead. Because the price of hot dogs and the quantity of hamburgers demanded move in the same direction, the cross-price elasticity is positive. Conversely, complements are goods that are typically used together, such as computers and software. In this case, the cross-price elasticity is negative, indicating that an increase in the price of computers reduces the quantity of software demanded.

**QUICK QUIZ:** Define the price elasticity of demand. ♦ Explain the relationship between total revenue and the price elasticity of demand.

## THE ELASTICITY OF SUPPLY

When we discussed the determinants of supply in Chapter 4, we noted that sellers of a good increase the quantity supplied when the price of the good rises, when their input prices fall, or when their technology improves. To turn from qualitative to quantitative statements about supply, we once again use the concept of elasticity.

### price elasticity of supply

*a measure of how much the quantity supplied of a good responds to a change in the price of that good, computed as the percentage change in quantity supplied divided by the percentage change in price*

## THE PRICE ELASTICITY OF SUPPLY AND ITS DETERMINANTS

The law of supply states that higher prices raise the quantity supplied. The **price elasticity of supply** measures how much the quantity supplied responds to changes in the price. Supply of a good is said to be *elastic* if the quantity supplied

responds substantially to changes in the price. Supply is said to be *inelastic* if the quantity supplied responds only slightly to changes in the price.

The price elasticity of supply depends on the flexibility of sellers to change the amount of the good they produce. For example, beachfront land has an inelastic supply because it is almost impossible to produce more of it. By contrast, manufactured goods, such as books, cars, and televisions, have elastic supplies because the firms that produce them can run their factories longer in response to a higher price.

In most markets, a key determinant of the price elasticity of supply is the time period being considered. Supply is usually more elastic in the long run than in the short run. Over short periods of time, firms cannot easily change the size of their factories to make more or less of a good. Thus, in the short run, the quantity supplied is not very responsive to the price. By contrast, over longer periods, firms can build new factories or close old ones. In addition, new firms can enter a market, and old firms can shut down. Thus, in the long run, the quantity supplied can respond substantially to the price.

### COMPUTING THE PRICE ELASTICITY OF SUPPLY

Now that we have some idea about what the price elasticity of supply is, let's be more precise. Economists compute the price elasticity of supply as the percentage change in the quantity supplied divided by the percentage change in the price. That is,

$$\text{Price elasticity of supply} = \frac{\text{Percentage change in quantity supplied}}{\text{Percentage change in price}}.$$

For example, suppose that an increase in the price of milk from \$2.85 to \$3.15 a gallon raises the amount that dairy farmers produce from 9,000 to 11,000 gallons per month. Using the midpoint method, we calculate the percentage change in price as

$$\text{Percentage change in price} = (3.15 - 2.85)/3.00 \times 100 = 10 \text{ percent.}$$

Similarly, we calculate the percentage change in quantity supplied as

$$\begin{aligned} \text{Percentage change in quantity supplied} &= (11,000 - 9,000)/10,000 \times 100 \\ &= 20 \text{ percent.} \end{aligned}$$

In this case, the price elasticity of supply is

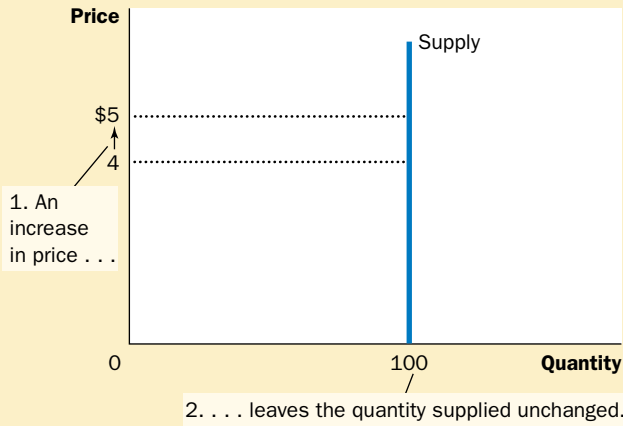
$$\text{Price elasticity of supply} = \frac{20 \text{ percent}}{10 \text{ percent}} = 2.0.$$

In this example, the elasticity of 2 reflects the fact that the quantity supplied moves proportionately twice as much as the price.

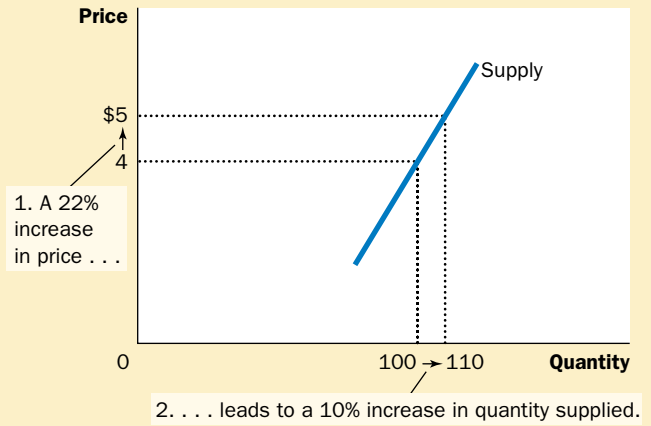
### THE VARIETY OF SUPPLY CURVES

Because the price elasticity of supply measures the responsiveness of quantity supplied to the price, it is reflected in the appearance of the supply curve. Figure 5-6 shows five cases. In the extreme case of a zero elasticity, supply is *perfectly inelastic*,

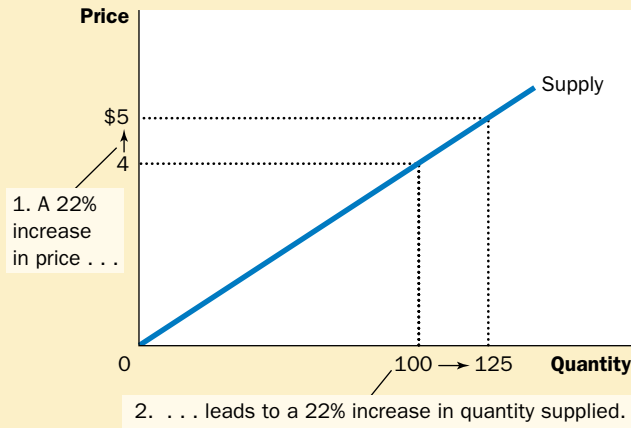
(a) Perfectly Inelastic Supply: Elasticity Equals 0



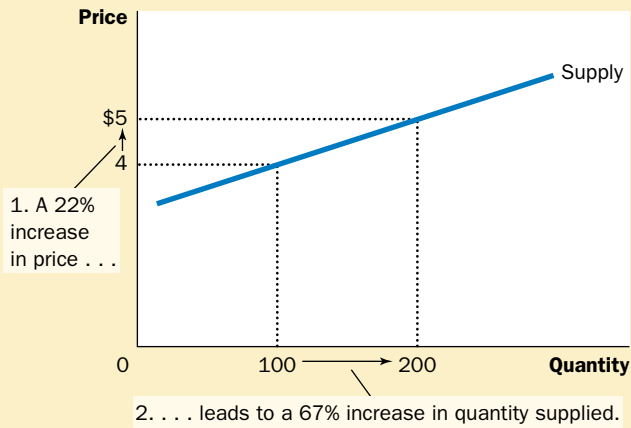
(b) Inelastic Supply: Elasticity Is Less Than 1



(c) Unit Elastic Supply: Elasticity Equals 1



(d) Elastic Supply: Elasticity Is Greater Than 1



(e) Perfectly Elastic Supply: Elasticity Equals Infinity

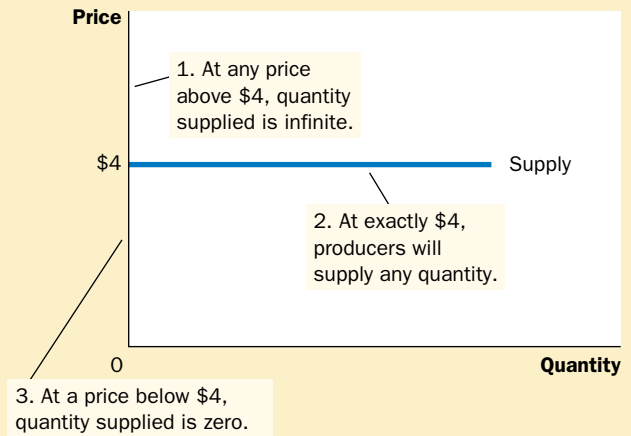
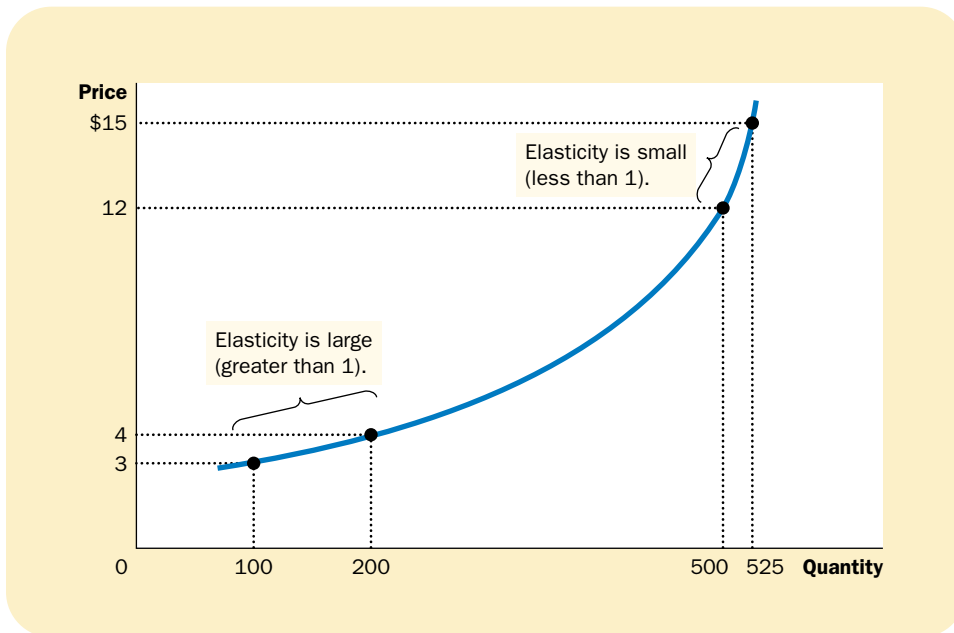


Figure 5-6

THE PRICE ELASTICITY OF SUPPLY. The price elasticity of supply determines whether the supply curve is steep or flat. Note that all percentage changes are calculated using the midpoint method.

**Figure 5-7**

HOW THE PRICE ELASTICITY OF SUPPLY CAN VARY. Because firms often have a maximum capacity for production, the elasticity of supply may be very high at low levels of quantity supplied and very low at high levels of quantity supplied. Here, an increase in price from \$3 to \$4 increases the quantity supplied from 100 to 200. Because the increase in quantity supplied of 100 percent is larger than the increase in price of 33 percent, the supply curve is elastic in this range. By contrast, when the price rises from \$12 to \$15, the quantity supplied rises only from 500 to 525. Because the increase in quantity supplied of 5 percent is smaller than the increase in price of 25 percent, the supply curve is inelastic in this range.

and the supply curve is vertical. In this case, the quantity supplied is the same regardless of the price. As the elasticity rises, the supply curve gets flatter, which shows that the quantity supplied responds more to changes in the price. At the opposite extreme, supply is *perfectly elastic*. This occurs as the price elasticity of supply approaches infinity and the supply curve becomes horizontal, meaning that very small changes in the price lead to very large changes in the quantity supplied.

In some markets, the elasticity of supply is not constant but varies over the supply curve. Figure 5-7 shows a typical case for an industry in which firms have factories with a limited capacity for production. For low levels of quantity supplied, the elasticity of supply is high, indicating that firms respond substantially to changes in the price. In this region, firms have capacity for production that is not being used, such as plants and equipment sitting idle for all or part of the day. Small increases in price make it profitable for firms to begin using this idle capacity. As the quantity supplied rises, firms begin to reach capacity. Once capacity is fully used, increasing production further requires the construction of new plants. To induce firms to incur this extra expense, the price must rise substantially, so supply becomes less elastic.

Figure 5-7 presents a numerical example of this phenomenon. When the price rises from \$3 to \$4 (a 29 percent increase, according to the midpoint method), the quantity supplied rises from 100 to 200 (a 67 percent increase). Because quantity supplied moves proportionately more than the price, the supply curve has elasticity greater than 1. By contrast, when the price rises from \$12 to \$15 (a 22 percent increase), the quantity supplied rises from 500 to 525 (a 5 percent increase). In this case, quantity supplied moves proportionately less than the price, so the elasticity is less than 1.

**QUICK QUIZ:** Define the price elasticity of supply. ♦ Explain why the price elasticity of supply might be different in the long run than in the short run.

### THREE APPLICATIONS OF SUPPLY, DEMAND, AND ELASTICITY

Can good news for farming be bad news for farmers? Why did the Organization of Petroleum Exporting Countries (OPEC) fail to keep the price of oil high? Does drug interdiction increase or decrease drug-related crime? At first, these questions might seem to have little in common. Yet all three questions are about markets, and all markets are subject to the forces of supply and demand. Here we apply the versatile tools of supply, demand, and elasticity to answer these seemingly complex questions.

#### CAN GOOD NEWS FOR FARMING BE BAD NEWS FOR FARMERS?

Let's now return to the question posed at the beginning of this chapter: What happens to wheat farmers and the market for wheat when university agronomists discover a new wheat hybrid that is more productive than existing varieties? Recall from Chapter 4 that we answer such questions in three steps. First, we examine whether the supply curve or demand curve shifts. Second, we consider which direction the curve shifts. Third, we use the supply-and-demand diagram to see how the market equilibrium changes.

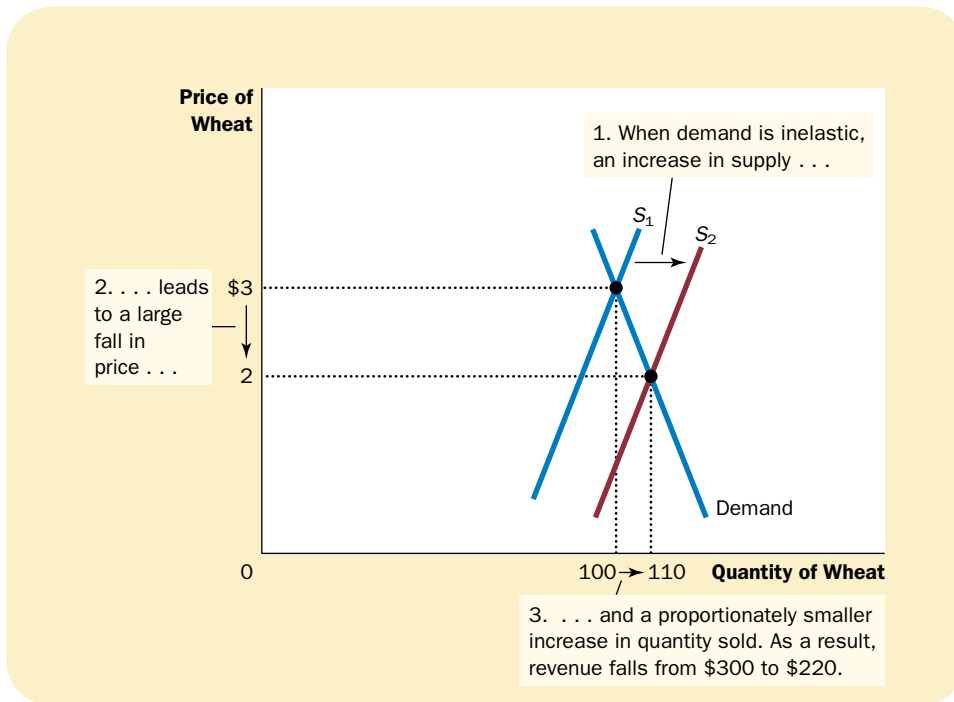
In this case, the discovery of the new hybrid affects the supply curve. Because the hybrid increases the amount of wheat that can be produced on each acre of land, farmers are now willing to supply more wheat at any given price. In other words, the supply curve shifts to the right. The demand curve remains the same because consumers' desire to buy wheat products at any given price is not affected by the introduction of a new hybrid. Figure 5-8 shows an example of such a change. When the supply curve shifts from  $S_1$  to  $S_2$ , the quantity of wheat sold increases from 100 to 110, and the price of wheat falls from \$3 to \$2.

But does this discovery make farmers better off? As a first cut to answering this question, consider what happens to the total revenue received by farmers. Farmers' total revenue is  $P \times Q$ , the price of the wheat times the quantity sold. The discovery affects farmers in two conflicting ways. The hybrid allows farmers to produce more wheat ( $Q$  rises), but now each bushel of wheat sells for less ( $P$  falls).

Whether total revenue rises or falls depends on the elasticity of demand. In practice, the demand for basic foodstuffs such as wheat is usually inelastic, for these items are relatively inexpensive and have few good substitutes. When the demand curve is inelastic, as it is in Figure 5-8, a decrease in price causes total revenue to fall. You can see this in the figure: The price of wheat falls substantially, whereas the quantity of wheat sold rises only slightly. Total revenue falls from \$300 to \$220. Thus, the discovery of the new hybrid lowers the total revenue that farmers receive for the sale of their crops.

If farmers are made worse off by the discovery of this new hybrid, why do they adopt it? The answer to this question goes to the heart of how competitive markets work. Because each farmer is a small part of the market for wheat, he or she takes the price of wheat as given. For any given price of wheat, it is better to

Figure 5-8



AN INCREASE IN SUPPLY IN THE MARKET FOR WHEAT. When an advance in farm technology increases the supply of wheat from  $S_1$  to  $S_2$ , the price of wheat falls. Because the demand for wheat is inelastic, the increase in the quantity sold from 100 to 110 is proportionately smaller than the decrease in the price from \$3 to \$2. As a result, farmers' total revenue falls from \$300 ( $\$3 \times 100$ ) to \$220 ( $\$2 \times 110$ ).

use the new hybrid in order to produce and sell more wheat. Yet when all farmers do this, the supply of wheat rises, the price falls, and farmers are worse off.

Although this example may at first seem only hypothetical, in fact it helps to explain a major change in the U.S. economy over the past century. Two hundred years ago, most Americans lived on farms. Knowledge about farm methods was sufficiently primitive that most of us had to be farmers in order to produce enough food. Yet, over time, advances in farm technology increased the amount of food that each farmer could produce. This increase in food supply, together with inelastic food demand, caused farm revenues to fall, which in turn encouraged people to leave farming.

A few numbers show the magnitude of this historic change. As recently as 1950, there were 10 million people working on farms in the United States, representing 17 percent of the labor force. In 1998, fewer than 3 million people worked on farms, or 2 percent of the labor force. This change coincided with tremendous advances in farm productivity: Despite the 70 percent drop in the number of farmers, U.S. farms produced more than twice the output of crops and livestock in 1998 as they did in 1950.

This analysis of the market for farm products also helps to explain a seeming paradox of public policy: Certain farm programs try to help farmers by inducing them not to plant crops on all of their land. Why do these programs do this? Their purpose is to reduce the supply of farm products and thereby raise prices. With inelastic demand for their products, farmers as a group receive greater total revenue if they supply a smaller crop to the market. No single farmer would choose to leave his land fallow on his own because each takes the market price as given. But if all farmers do so together, each of them can be better off.

# Doonesbury

by G.B. TRUDEAU



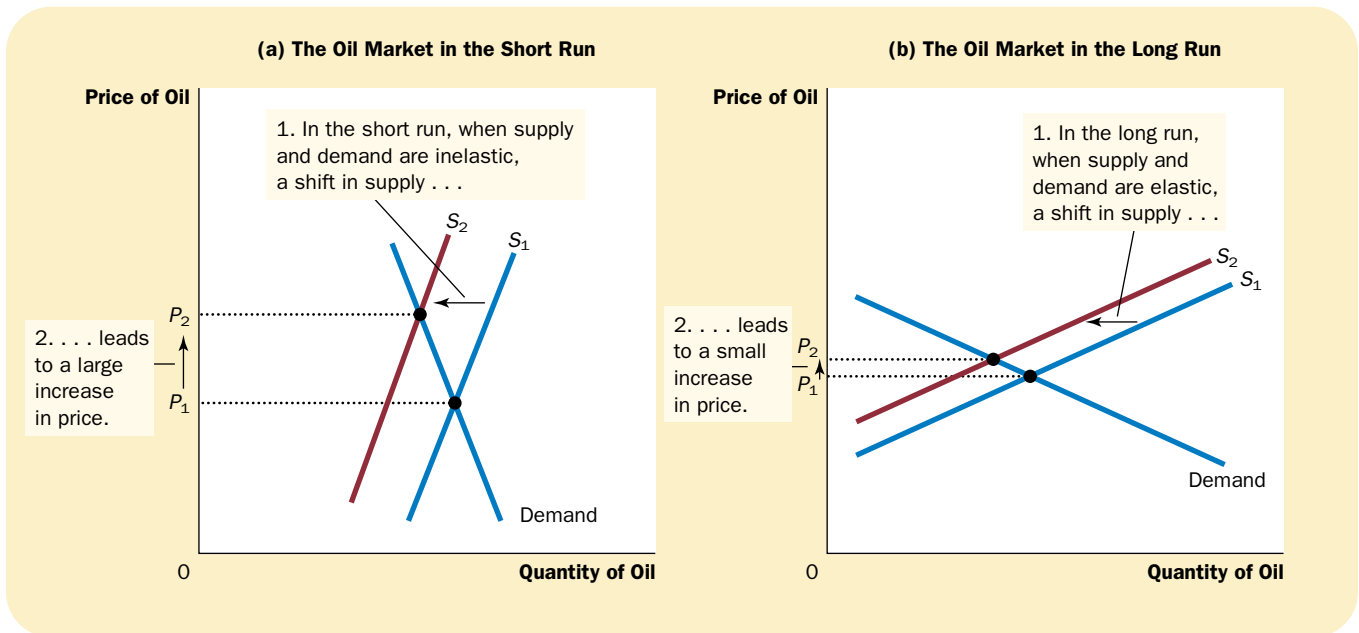
When analyzing the effects of farm technology or farm policy, it is important to keep in mind that what is good for farmers is not necessarily good for society as a whole. Improvement in farm technology can be bad for farmers who become increasingly unnecessary, but it is surely good for consumers who pay less for food. Similarly, a policy aimed at reducing the supply of farm products may raise the incomes of farmers, but it does so at the expense of consumers.

## WHY DID OPEC FAIL TO KEEP THE PRICE OF OIL HIGH?

Many of the most disruptive events for the world's economies over the past several decades have originated in the world market for oil. In the 1970s members of the Organization of Petroleum Exporting Countries (OPEC) decided to raise the world price of oil in order to increase their incomes. These countries accomplished this goal by jointly reducing the amount of oil they supplied. From 1973 to 1974, the price of oil (adjusted for overall inflation) rose more than 50 percent. Then, a few years later, OPEC did the same thing again. The price of oil rose 14 percent in 1979, followed by 34 percent in 1980, and another 34 percent in 1981.

Yet OPEC found it difficult to maintain a high price. From 1982 to 1985, the price of oil steadily declined at about 10 percent per year. Dissatisfaction and disarray soon prevailed among the OPEC countries. In 1986 cooperation among OPEC members completely broke down, and the price of oil plunged 45 percent. In 1990 the price of oil (adjusted for overall inflation) was back to where it began in 1970, and it has stayed at that low level throughout most of the 1990s.

This episode shows how supply and demand can behave differently in the short run and in the long run. In the short run, both the supply and demand for oil are relatively inelastic. Supply is inelastic because the quantity of known oil reserves and the capacity for oil extraction cannot be changed quickly. Demand is inelastic because buying habits do not respond immediately to changes in price. Many drivers with old gas-guzzling cars, for instance, will just pay the higher



**A REDUCTION IN SUPPLY IN THE WORLD MARKET FOR OIL.** When the supply of oil falls, the response depends on the time horizon. In the short run, supply and demand are relatively inelastic, as in panel (a). Thus, when the supply curve shifts from  $S_1$  to  $S_2$ , the price rises substantially. By contrast, in the long run, supply and demand are relatively elastic, as in panel (b). In this case, the same size shift in the supply curve ( $S_1$  to  $S_2$ ) causes a smaller increase in the price.

**Figure 5-9**

price. Thus, as panel (a) of Figure 5-9 shows, the short-run supply and demand curves are steep. When the supply of oil shifts from  $S_1$  to  $S_2$ , the price increase from  $P_1$  to  $P_2$  is large.

The situation is very different in the long run. Over long periods of time, producers of oil outside of OPEC respond to high prices by increasing oil exploration and by building new extraction capacity. Consumers respond with greater conservation, for instance by replacing old inefficient cars with newer efficient ones. Thus, as panel (b) of Figure 5-9 shows, the long-run supply and demand curves are more elastic. In the long run, the shift in the supply curve from  $S_1$  to  $S_2$  causes a much smaller increase in the price.

This analysis shows why OPEC succeeded in maintaining a high price of oil only in the short run. When OPEC countries agreed to reduce their production of oil, they shifted the supply curve to the left. Even though each OPEC member sold less oil, the price rose by so much in the short run that OPEC incomes rose. By contrast, in the long run when supply and demand are more elastic, the same reduction in supply, measured by the horizontal shift in the supply curve, caused a smaller increase in the price. Thus, OPEC's coordinated reduction in supply proved less profitable in the long run.

OPEC still exists today. You will occasionally hear in the news about meetings of officials from the OPEC countries. Cooperation among OPEC countries is less

common now, however, in part because of the organization's past failure at maintaining a high price.

### DOES DRUG INTERDICTION INCREASE OR DECREASE DRUG-RELATED CRIME?

A persistent problem facing our society is the use of illegal drugs, such as heroin, cocaine, and crack. Drug use has several adverse effects. One is that drug dependency can ruin the lives of drug users and their families. Another is that drug addicts often turn to robbery and other violent crimes to obtain the money needed to support their habit. To discourage the use of illegal drugs, the U.S. government devotes billions of dollars each year to reduce the flow of drugs into the country. Let's use the tools of supply and demand to examine this policy of drug interdiction.

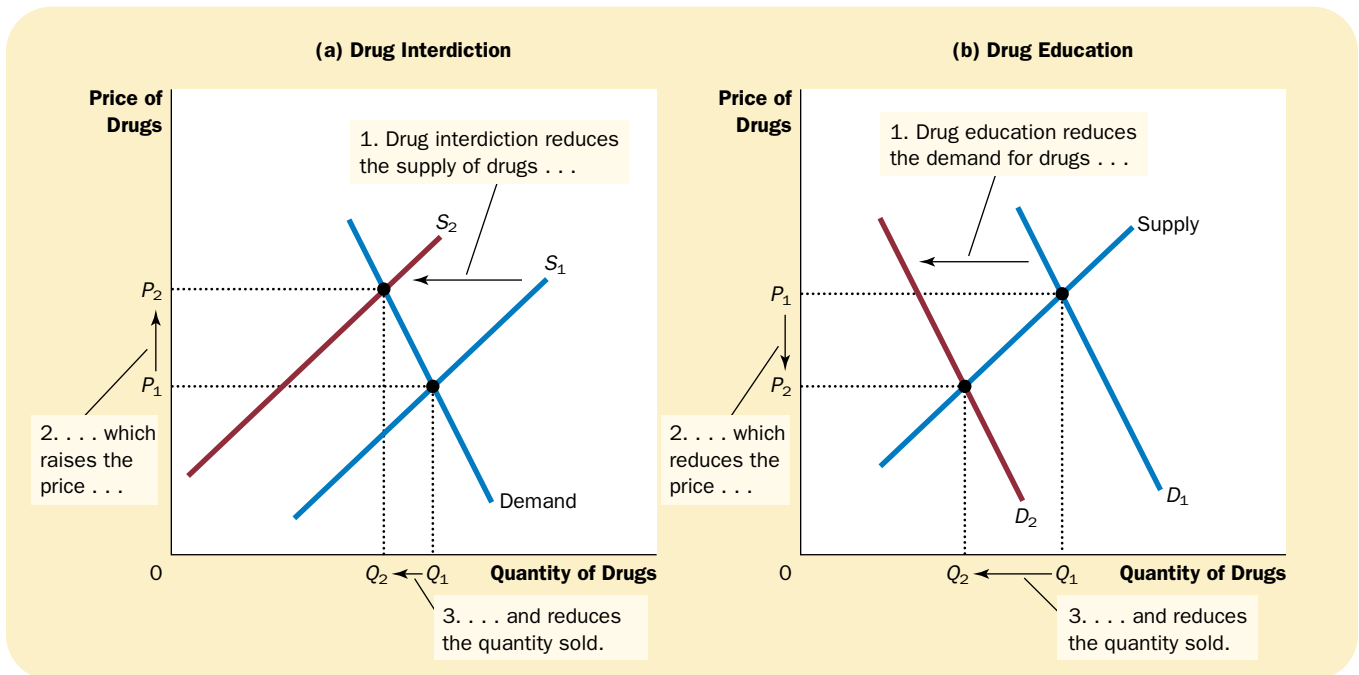
Suppose the government increases the number of federal agents devoted to the war on drugs. What happens in the market for illegal drugs? As is usual, we answer this question in three steps. First, we consider whether the supply curve or demand curve shifts. Second, we consider the direction of the shift. Third, we see how the shift affects the equilibrium price and quantity.

Although the purpose of drug interdiction is to reduce drug use, its direct impact is on the sellers of drugs rather than the buyers. When the government stops some drugs from entering the country and arrests more smugglers, it raises the cost of selling drugs and, therefore, reduces the quantity of drugs supplied at any given price. The demand for drugs—the amount buyers want at any given price—is not changed. As panel (a) of Figure 5-10 shows, interdiction shifts the supply curve to the left from  $S_1$  to  $S_2$  and leaves the demand curve the same. The equilibrium price of drugs rises from  $P_1$  to  $P_2$ , and the equilibrium quantity falls from  $Q_1$  to  $Q_2$ . The fall in the equilibrium quantity shows that drug interdiction does reduce drug use.

But what about the amount of drug-related crime? To answer this question, consider the total amount that drug users pay for the drugs they buy. Because few drug addicts are likely to break their destructive habits in response to a higher price, it is likely that the demand for drugs is inelastic, as it is drawn in the figure. If demand is inelastic, then an increase in price raises total revenue in the drug market. That is, because drug interdiction raises the price of drugs proportionately more than it reduces drug use, it raises the total amount of money that drug users pay for drugs. Addicts who already had to steal to support their habits would have an even greater need for quick cash. Thus, drug interdiction could increase drug-related crime.

Because of this adverse effect of drug interdiction, some analysts argue for alternative approaches to the drug problem. Rather than trying to reduce the supply of drugs, policymakers might try to reduce the demand by pursuing a policy of drug education. Successful drug education has the effects shown in panel (b) of Figure 5-10. The demand curve shifts to the left from  $D_1$  to  $D_2$ . As a result, the equilibrium quantity falls from  $Q_1$  to  $Q_2$ , and the equilibrium price falls from  $P_1$  to  $P_2$ . Total revenue, which is price times quantity, also falls. Thus, in contrast to drug interdiction, drug education can reduce both drug use and drug-related crime.

Advocates of drug interdiction might argue that the effects of this policy are different in the long run than in the short run, because the elasticity of demand may depend on the time horizon. The demand for drugs is probably inelastic over



**POLICIES TO REDUCE THE USE OF ILLEGAL DRUGS.** Drug interdiction reduces the supply of drugs from  $S_1$  to  $S_2$ , as in panel (a). If the demand for drugs is inelastic, then the total amount paid by drug users rises, even as the amount of drug use falls. By contrast, drug education reduces the demand for drugs from  $D_1$  to  $D_2$ , as in panel (b). Because both price and quantity fall, the amount paid by drug users falls.

**Figure 5-10**

short periods of time because higher prices do not substantially affect drug use by established addicts. But demand may be more elastic over longer periods of time because higher prices would discourage experimentation with drugs among the young and, over time, lead to fewer drug addicts. In this case, drug interdiction would increase drug-related crime in the short run while decreasing it in the long run.

**QUICK QUIZ:** How might a drought that destroys half of all farm crops be good for farmers? If such a drought is good for farmers, why don't farmers destroy their own crops in the absence of a drought?

## CONCLUSION

According to an old quip, even a parrot can become an economist simply by learning to say "supply and demand." These last two chapters should have convinced you that there is much truth in this statement. The tools of supply and demand allow you to analyze many of the most important events and policies that shape

the economy. You are now well on your way to becoming an economist (or, at least, a well-educated parrot).

### Summary

- ◆ The price elasticity of demand measures how much the quantity demanded responds to changes in the price. Demand tends to be more elastic if the good is a luxury rather than a necessity, if close substitutes are available, if the market is narrowly defined, or if buyers have substantial time to react to a price change.
- ◆ The price elasticity of demand is calculated as the percentage change in quantity demanded divided by the percentage change in price. If the elasticity is less than 1, so that quantity demanded moves proportionately less than the price, demand is said to be inelastic. If the elasticity is greater than 1, so that quantity demanded moves proportionately more than the price, demand is said to be elastic.
- ◆ Total revenue, the total amount paid for a good, equals the price of the good times the quantity sold. For inelastic demand curves, total revenue rises as price rises. For elastic demand curves, total revenue falls as price rises.
- ◆ The income elasticity of demand measures how much the quantity demanded responds to changes in consumers' income. The cross-price elasticity of demand measures how much the quantity demanded of one good responds to the price of another good.
- ◆ The price elasticity of supply measures how much the quantity supplied responds to changes in the price. This elasticity often depends on the time horizon under consideration. In most markets, supply is more elastic in the long run than in the short run.
- ◆ The price elasticity of supply is calculated as the percentage change in quantity supplied divided by the percentage change in price. If the elasticity is less than 1, so that quantity supplied moves proportionately less than the price, supply is said to be inelastic. If the elasticity is greater than 1, so that quantity supplied moves proportionately more than the price, supply is said to be elastic.
- ◆ The tools of supply and demand can be applied in many different kinds of markets. This chapter uses them to analyze the market for wheat, the market for oil, and the market for illegal drugs.

### Key Concepts

elasticity, p. xxx

price elasticity of demand, p. xxx

total revenue, p. xxx

income elasticity of demand, p. xxx

cross-price elasticity of demand, p. xxx

price elasticity of supply, p. xxx

### Questions for Review

1. Define the price elasticity of demand and the income elasticity of demand.
2. List and explain some of the determinants of the price elasticity of demand.
3. If the elasticity is greater than 1, is demand elastic or inelastic? If the elasticity equals 0, is demand perfectly elastic or perfectly inelastic?
4. On a supply-and-demand diagram, show equilibrium price, equilibrium quantity, and the total revenue received by producers?
5. If demand is elastic, how will an increase in price change total revenue? Explain.
6. What do we call a good whose income elasticity is less than 0?
7. How is the price elasticity of supply calculated? Explain what this measures.
8. What is the price elasticity of supply of Picasso paintings?
9. Is the price elasticity of supply usually larger in the short run or in the long run? Why?
10. In the 1970s, OPEC caused a dramatic increase in the price of oil. What prevented it from maintaining this high price through the 1980s?

### Problems and Applications

1. For each of the following pairs of goods, which good would you expect to have more elastic demand and why?
  - a. required textbooks or mystery novels
  - b. Beethoven recordings or classical music recordings in general
  - c. heating oil during the next six months or heating oil during the next five years
  - d. root beer or water
2. Suppose that business travelers and vacationers have the following demand for airline tickets from New York to Boston:

PRICE	QUANTITY DEMANDED (BUSINESS TRAVELERS)	QUANTITY DEMANDED (VACATIONERS)
\$150	2,100	1,000
200	2,000	800
250	1,900	600
300	1,800	400

- a. As the price of tickets rises from \$200 to \$250, what is the price elasticity of demand for (i) business travelers and (ii) vacationers? (Use the midpoint method in your calculations.)
  - b. Why might vacationers have a different elasticity than business travelers?
3. Suppose that your demand schedule for compact discs is as follows:

PRICE	QUANTITY DEMANDED (INCOME = \$10,000)	QUANTITY DEMANDED (INCOME = \$12,000)
\$ 8	40	50
10	32	45
12	24	30
14	16	20
16	8	12

- a. Use the midpoint method to calculate your price elasticity of demand as the price of compact discs increases from \$8 to \$10 if (i) your income is \$10,000, and (ii) your income is \$12,000.
  - b. Calculate your income elasticity of demand as your income increases from \$10,000 to \$12,000 if (i) the price is \$12, and (ii) the price is \$16.
4. Emily has decided always to spend one-third of her income on clothing.
    - a. What is her income elasticity of clothing demand?

- b. What is her price elasticity of clothing demand?
  - c. If Emily's tastes change and she decides to spend only one-fourth of her income on clothing, how does her demand curve change? What are her income elasticity and price elasticity now?
5. *The New York Times* reported (Feb. 17, 1996, p. 25) that subway ridership declined after a fare increase: "There were nearly four million fewer riders in December 1995, the first full month after the price of a token increased 25 cents to \$1.50, than in the previous December, a 4.3 percent decline."
    - a. Use these data to estimate the price elasticity of demand for subway rides.
    - b. According to your estimate, what happens to the Transit Authority's revenue when the fare rises?
    - c. Why might your estimate of the elasticity be unreliable?
  6. Two drivers—Tom and Jerry—each drive up to a gas station. Before looking at the price, each places an order. Tom says, "I'd like 10 gallons of gas." Jerry says, "I'd like \$10 of gas." What is each driver's price elasticity of demand?
  7. Economists have observed that spending on restaurant meals declines more during economic downturns than does spending on food to be eaten at home. How might the concept of elasticity help to explain this phenomenon?
  8. Consider public policy aimed at smoking.
    - a. Studies indicate that the price elasticity of demand for cigarettes is about 0.4. If a pack of cigarettes currently costs \$2 and the government wants to reduce smoking by 20 percent, by how much should it increase the price?
    - b. If the government permanently increases the price of cigarettes, will the policy have a larger effect on smoking one year from now or five years from now?
    - c. Studies also find that teenagers have a higher price elasticity than do adults. Why might this be true?
  9. Would you expect the price elasticity of *demand* to be larger in the market for all ice cream or the market for vanilla ice cream? Would you expect the price elasticity of *supply* to be larger in the market for all ice cream or the market for vanilla ice cream? Be sure to explain your answers.
  10. Pharmaceutical drugs have an inelastic demand, and computers have an elastic demand. Suppose that

- technological advance doubles the supply of both products (that is, the quantity supplied at each price is twice what it was).
- a. What happens to the equilibrium price and quantity in each market?
  - b. Which product experiences a larger change in price?
  - c. Which product experiences a larger change in quantity?
  - d. What happens to total consumer spending on each product?
11. Beachfront resorts have an inelastic supply, and automobiles have an elastic supply. Suppose that a rise in population doubles the demand for both products (that is, the quantity demanded at each price is twice what it was).
- a. What happens to the equilibrium price and quantity in each market?
  - b. Which product experiences a larger change in price?
  - c. Which product experiences a larger change in quantity?
  - d. What happens to total consumer spending on each product?
12. Several years ago, flooding along the Missouri and Mississippi rivers destroyed thousands of acres of wheat.
- a. Farmers whose crops were destroyed by the floods were much worse off, but farmers whose crops were not destroyed benefited from the floods. Why?
  - b. What information would you need about the market for wheat in order to assess whether farmers as a group were hurt or helped by the floods?
13. Explain why the following might be true: A drought around the world raises the total revenue that farmers receive from the sale of grain, but a drought only in Kansas reduces the total revenue that Kansas farmers receive.
14. Because better weather makes farmland more productive, farmland in regions with good weather conditions is more expensive than farmland in regions with bad weather conditions. Over time, however, as advances in technology have made all farmland more productive, the price of farmland (adjusted for overall inflation) has fallen. Use the concept of elasticity to explain why productivity and farmland prices are positively related across space but negatively related over time.